CHAPTER 12

EMISSION CONTROL EQUIPMENT SELECTION FOR INCINERATORS AND BOILERS

12-1. Principles of selection

a. Selection of emission control equipment is made in three basic steps.

(1) *Performance.* The control equipment must be capable of continuously controlling the emission of the pollutant below the permitted quantities. The equipment type and design should have a proven record of meeting the required removal or collection efficiency and the manufacturer should guarantee the equipment for continuous performance.

(2) *Construction.* The materials of construction should be compatible with the characteristics and constituents in the flue gases. Materials should be resistant to erosion and corrosion and should be suitable for the operating temperatures. The unit should have adequate access manholes and service platforms and stairs to inspect and maintain the equipment. Units should be adequately insulated and weather protected.

(3) *Operation.* Where more than one design or type of device can provide the necessary pollution control it then becomes necessary to evaluate the various designs based on a life-cycle cost-analysis, and the ease of operation.

b. Preliminary information which is needed to properly select pollution control equipment are as follows:

(1) Site-specific emissions limitations for the stack serving the particular boiler or incinerator must be determined for the applicable source and ambient condition. This information is to be derived from existing federal, state and local regulations.

(2) Obtain detailed descriptions of the boiler or incinerator including the combustion control system(s) and all support auxiliaries including outline drawings available from the manufacturers; and the predicted uncontrolled, gaseous emissions established for the units.

(3) For the particular fuel to be burned, determine the method of firing and maximum continuous rated heat input per British Thermal Units per hour (BTU's/Hr) along with applicable combustion calculations for normal and upset operating conditions. This may require a fuel analysis. In the case of coal firing the analysis should include ultimate and proximate properties and an analysis of the residual ash.

(4) Obtain required construction and operations permit forms from applicable regulatory agencies, complete, and submit where required.

(5) Obtain the requirements and restraints for disposing of the collected pollutant. Under some circumstances such as preliminary studies it becomes necessary to calculate the process data and then use empirical data to estimate the emission quantities.

c. The U.S. Environmental Protection Agency (EPA) has published a Technical Manual 'AP-42" and excerpts from the EPA publication have been reproduced and included in Chapters 2 and 3 of this manual to be used as a guide for predicting the emissions that will be generated by various fuels and combustions apparatus.

d. Present emissions control requirements and laws are complicated and stringent, and emission control equipment represents a significant portion of the combustion equipment costs. Inadequately specified or applied control devices could be a very costly error. It is advisable wherever possible to utilize qualified engineers experienced in boiler or incinerator plant designs and operation of such tasks. It is beneficial for the engineer to also have experience in securing necessary permits.

12-2. Flue gas properties

a. Gas properties influence the design and performance of the pollution control equipment. When working with a particular emission standard or code the gas properties must be converted to the units used in the codes, such as lbs per million BTU; gr/ACFM; DSCFM at 32; DSCFM at 68; DSCFM corrected to 8 percent 0_2.

b. Flow rate. The flow-rate of exhaust gases generated in the combustion process must be measured or calculated to determine the required volumetric size of the collection equipment. Flow-rate variations result in velocity changes and thus influence collector efficiency and pressure drop. It is necessary therefore to obtain maximum, average, and minimum values for a cyclical or modulating operation.

c. Temperature. Gas temperature affects gas volume (and simultaneously collector volume) and materials of construction for the collector. Temperature may also limit use of certain collectors. For instance, temperatures above 550 degree Fahrenheit rule out the use of fabric filters.

d. Pressure. Carrier gas pressure must be known or calculated to determine the structural requirements for the collector under operating and upset conditions.

e. Viscosity. Gas viscosity is a measure of molecular activity in a gas stream. The greater the gas viscosity, the greater the resistance to particle migration across the stream normal to gas flow. Since gas viscosity increases with gas temperature, it is an important factor in the performance of dry particulate collection devices. viscosity effects can be minimized if equipment is properly specified.

f. Moisture content. Moisture content affects the performance of collection equipment and the choice of construction materials. It is important to know the dew point of the exhaust gas, as temperatures below dew point allows acid vapors to condense and attack structural surfaces. This is a particular concern with boiler flue-gas which often contains a significant amount of sulfuric acid vapor.

g. Chemical composition. Chemical composition primarily affects the choice of construction materials for a collector. Collectors must be suitably protected to handle corrosive gases.

h. Toxicity. Handling of toxic gases requires special treatment and equipment and must be reviewed on an individual basis. This manual does not address incineration of toxic or hazardous wastes.

12-3. Particulate properties

a. Particulate properties that must be determined for control equipment selection and design are described below. Appropriate test methods are listed in table 5-1.

b. Concentration (loading). Particulate loading is a measurement of particulate concentration in flue gases (see this manual, chapters 2 and 3) expressed in grains per cubic foot. Particulate loading is used as a criteria to design and select applicable collection equipment. Fluctuations in loading (for example: soot blowing in boilers) must be noted and maximum, minimum, and average values should be recorded. High grain loadings may require a series system of control devices to meet particulate emissions and air quality standards. For instance, a cyclone followed by an electrostatic precipitator or baghouse.

c. Particle size. The particle size analysis affects the collection efficiency for each control device. Fine particulate collection requires high-efficiency equipment such as venturi scrubbers, electrostatic precipitators, or fabric filters.

d. Resistivity. Particulate resistivity is a limiting factor in the design of electrostatic precipitators. Resistivity must be determined if an electrostatic precipitator is to be selected to control particulate emissions. As a general guideline, resistivity above 1010 ohm-cm normally rules out the use of electrostatic precipitation unless provisions are made for particulate electrical conditioning.

e. Handling characteristics. Particle-handling characteristics influence dust-handling systems (ductwork, collector structure, hoppers, conveyors) and materials of construction. Dust-handling characteristics include flow properties, abrasiveness, hygroscopicity, moisture content, agglomerating tendencies. These properties, including specific gravity and bulk density should be evaluated in the design of a dust-collecting system.

f. Chemical composition. Chemical composition of particulate affects materials of construction and design of the collector and ash disposal equipment as does carrier gas composition.

12-4. Application of emission control systems for boilers.

As a result of current, stringent, stack emission regulations, applications of certain conventional emissions control systems have evolved that provide satisfactory performance when properly sized and specified. Referenced are CFR40 part 60 for new source performance standards (NSPS) only, as ambient regulations have wide variation from site-to-site requiring investigation for each location. Following is a brief description of the most common combustion sources, fuels, and control devices employed:

a. Natural gas fired power boiler. NSPS cover particulates; sulfur dioxide SO_2; nitrogen dioxide NO_x; and opacity.

(1) External devices are not usually required. Properly adjusted combustion controls, burner(s), furnace designs, and gas monitoring are sufficient to meet the performance standards.

(2) Even though natural gas is a relatively clean fuel, some emissions can occur from the combustion reaction. For example, improper operating conditions, including items such as poor mixing and insufficient air, may cause large amounts of smoke, carbon monoxide, and hydrocarbons to be produced. Moreover, because a sulfur-containing mercaptan is added to natural gas for detection proposes, small amounts of sulfur oxides will also be produced in the combustion process.

(3) Nitrogen oxides are the major pollutants of concern when burning natural gas. Nitrogen dioxide emissions are a function of the temperature in the combustion chamber and the rate of cooling of the combustion products.

Emission levels generally vary considerably with the type and size of unit and are also a function of loading.

(4) In some large boilers, several operating modifications have been employed for NO_x control. In staged combustion, for example, including off-stoichiometric firing, also called "biased firming," some burners are operated fuel-rich, some fuel-lean, while others may supply air only. In two-staged combustion, the burners are operated fuel-rich (by introducing only 80 to 95 percent stoichiometric air) with combustion being completed by air injected above the flame zone through second-stage “NO_x -ports”. In staged combustion, NO_x emissions are reduced because the bulk of combustion occurs under fuel-rich, reducing conditions.

b. Distillate oil fired power boilers. NSPS cover particulates; SO_2; NO_x; and opacity. Methods of modifying or controlling emissions are discussed in the following.

(1) *Particulate.* The user should note that in most cases external pollution control devices are not required for boilers firing No.1 or No.2 fuel oils.

(2) *SO_x.* Most distillates will contain sulfur quantities low enough so that no treatment will be necessary. However, a fuel analysis must be reviewed as some distillates can have as much as one percent sulfur. When the sulfur content produces SO_2 emissions in excess of the allowable a wet scrubbing system will be required.

(3) NO_x. Control requires the proper combustion controls, and burners and furnaces designed to limit NO_x generation from high combustion temperatures. Usually NO_x reductions are accomplished by limiting excess air firing and staged combustion. Large utility system units sometimes also employ flue-gas recirculation in addition to the other methods.

(4) *Opacity*. This may be controlled by proper air-fuel ratios; good combustion controls; limiting particulate emissions; and proper engineering design of the burners and furnace chamber.

c. Residual oil fired power boilers. NSPS cover particulates; SO_2; NO_x; and opacity. Methods of modifying or controlling emissions are discussed in the following.

(1) *Particulate control.*

(a) When using low-sulfur oils, cyclonic mechanical collectors are usually adequate. On larger utility size units electrostatic precipitators are employed to limit particulate emissions.

(b) For emissions from combustion of high-sulfur oils a wet scrubbing system can be used for both SO_2 removal and particulate control.

(2) *SO_2.* Use wet scrubbing system with a low pressure drop.

(3) NO_x. May be controlled by utilizing limited excess-air firing; flue gas recirculation; staged combustion; or combinations of these.

(4) *Opacity.* May be controlled by limiting or collecting the particulates and by properly adjusted and designed combustion controls with good burner and furnace designs.

d. Pulverized coal-fired power boiler. NSPS cover limitations for particulates; SO_2; NO_x; and opacity. Methods of modifying or controlling emissions are discussed in the following.

(1) *Particulates.*

(a) Control by use of electrostatic precipitator

(b) Control by use of fabric filters

(c) Control by use of venturi scrubber

(d) Control by combination of a mechanical collector followed by either (a), (b), or (c), above

(2) *SO_2.*

(a) Use suitable wet scrubber (can double for both SO_2 and particulates)

(b) Use suitable dry scrubber followed by fabric filters or electrostatic precipitator

(c) Selection of a wet or dry scrubbing system is determined by evaluating the economics (installation and operating costs) and the disposal of the collected pollutant.

(3) *NO_x.* Ensure that the burner and furnace are designed for limited excess-air firing and staged combustion. In some cases it may be necessary to have a second stage air fan designated as an NO_x control fan in order to gain compliance.

(4) *Opacity*. This may be controlled by particulate removal and properly adjusted combustion controls. In some cases this could be the more stringent requirement for particulate removal.

e. Spreader and mass feed stoker coal fired boilers with a traveling grate. NSPS cover limitations for particulates; SO_2; NO_x; and opacity. Methods of modifying or controlling emissions are discussed in the following.

(1) *Particulates.*

(a) Control by use of electrostatic precipitator

(b) Control by use of suitable fabric filter

(c) Control by use of suitable wet scrubber

(d) Control by a combination of a mechanical collector followed by either (a), (b), or (c) above

(2) *SO_2.*

(a) Use suitable wet scrubber (can double for both SO_2 and particulate).

(b) Use suitable dry scrubber followed by either a fabric filter or an electrostatic precipitator

(3) *NO_x*. Control by specifying furnace and combustion air controls designed to maintain limited flame temperatures under operating conditions.

(4) *Opacity*. Control by particulate removal and properly adjusted combustion controls. This can be the more stringent requirement for particulate removal.

f. Wood waste and bark fired boilers. NSPS cover limitation for particulates and opacity. Methods of modifying or controlling emissions are discussed in the following.

(1) *Particulates.*

(a) Control by use of a mechanical collector followed by either a scrubber or an electrostatic precipitator.

(b) Control by use of wet scrubber.

(c) Control by use of electrostatic precipitator.

(d) Control by use of gravel bed filter.

(2) *Opacity*. Opacity is controlled by particulate collection and properly adjusted combustion controls. The "as-fired" condition of wood waste fuel will impact the choice of particulate control equipment.

(a) Hogged bark and wood chips with 45% to 55% moisture usually require a mechanical collector followed by a scrubber or an E SP. Material collected in the mechanical collector is a combination of char, ash, and sand. The material is classified to separate the char from the ash/sand mixture so the char can be reinjected into the furnace combustion zone. The ash/sand mixture is discharged by gravity or conveyor to a holding tank which can be either wet or dry. All ash-hopper discharge openings must be protected from air infiltration by rotary-seal discharge valves or an air-lock damper arrangement, to prevent ignition of hot combustibles.

(b) Dry wood wastes that are chipped to less than 1" x ½" size may not require the mechanical collector and reinjection equipment. Gas clean-up equipment of choice may then be either the scrubber or electrostatic precipitator. Ash discharge hoppers need to be protected by seal valves or air locks in all cases.

(c) Fabric filters are avoided because of the potential for burning the fabric with hot char carry over.

(d) Ash handling is usually accomplished using a hydraulic conveying system discharging to an ash settling pond.

(e) Screw conveyors or drag-chain conveyors are acceptable alternatives for dry handling of ash from wood-fired boilers when ponding is not viable. The dry ash should be cooled and conditioned with water before being transported for land fill disposal.

g. Coal fired fluidized bed boilers. NSPS cover limitation for particulates; SO_2; NO_x; and opacity. Methods of modifying or controlling emissions are discussed in the following.

(1) *Particulates.* Control by use of fabric filter or an electrostatic precipitator. Most units will not require a mechanical collector in series with the baghouse or electrostatic precipitator. However, if high dust loadings are anticipated an in-line mechanical collector in series with the baghouse or electrostatic precipitator may be justified.

(2) *SO_2*. Controlled by the metering (feeding) of lime stone into the fluidized fuel bed.

(3) *NO_x*. The comparatively low furnace temperatures experienced in fluidized bed boilers limits the heat generated NO_x formation. No special devices or controls are required for NO_x control on fluidized bed units.

(4) *Opacity*. Controlled by particulate removal and properly adjusted and designed combustion controls.

(5) *Ash handling and removal systems.* Can be dry or wet and may be automated cycles or continuous ash removal utilizing equipment and methods previously discussed.

12-5. Municipal solid waste-fired boilers (MSW) and boilers using refuse derived fuels(RDF)

a. Municipal solid waste fired boilers fall in the same emission regulation category as an incinerator. Compliance is only required for particulate emission regulations.

b. Boilers using refuse derived fuels must meet the incinerator regulations and are also required to meet emission standards for any other fuels fired in the boiler. In most states the allowable emissions are calculated on the ratio of fuels fired and which cover control of particulate, SO_2, NO_x, and opacity.

(1) *Particulats* Use mechanical collectors as a primary device followed by either a fabric filter or an electrostatic precipitator. The ESP is favored when there is co-firing with coal in the MSW boiler. Without coal co-firing, resistivity of the particulate can be extremely high. Wet scrubbers should be avoided because of possible odor pick up.

(2) *SO_2*. SO_2 formation is a function of the sulfur content in the refuse and fuel. In most cases no SO_2 removal devices are necessary. However, when required a dry scrubber system followed by either a baghouse or an electrostatic precipitator is preferred.

(3) *NO_x*. Furnace design and firing methods are used to limit NO_x. Two-step combustion is employed. The primary zone is fired with limited air to maintain a reducing atmosphere and the secondary zone uses an oxidizing atmosphere to provide a controlled low-temperature flame with minimum excess air.

(4) *Opacity*. Opacity is controlled by limiting particulate emissions and by properly designed combustion controls.

12-6. Applications of emission control systems for incinerators

Refuse incinerators are type categorized as: municipal; industrial; commercial; and sludge. NSPS cover particulate emissions only. However, incineration of many solid, liquid, and gaseous wastes will produce noxious gases that require special treatment.

a. Municipal incinerators. Optimum control of incinerator particulate emissions begins with proper furnace design and careful operation. A proper design includes: a furnace/grate system appropriate to the waste; an adequate combustion gas retention time and velocity in the secondary combustion chamber; a suitable underfire and overfire air system; and establishing the optimum underfire/overfire air ratios.

(1) for compliance with NSPS it is necessary to utilize gas cleaning equipment and to optimize operating conditions for the furnace.

(2) Particulates. May be controlled with mechanical collectors; settling chambers; after burners; and low efficiency scrubbers used as precleaners. These must be followed by an electrostatic precipitator or a high efficiency venturi/orifice scrubber for final cleaning. Fabric filters may be used if emissions gas temperature is maintained below the maximum temperature rating of fabric media being used. This will usually require water spray injection for evaporative cooling of the gas stream.

(3) Odor control is frequently required and can be accomplished with after-burners strategically located in the furnace to oxidize the odorous gases.

b. !Industrial and commercial incinerators. Design of the incinerators and emissions control requirements are greatly influenced by the composition of the solid waste that is incinerated.

(1) Single chamber and conical (Teepee) type incinerators will not meet current NSPS emission requirements.

(2) Multiple chamber incinerators with controlled-combustion features, and fluidized-bed incinerators including sludge incinerators may be equipped with one or more of the previously discussed or following gas-cleaning systems to meet NSPS.

(3) When particulates are the controlled pollutant, primary collection devices commonly used are: after-burners; mechanical collectors; wetted baffles; and spray chambers.

(4) The final collection fo small particulate material is usually accomplished with one of the following devices:

— venturi or orifice-type scrubber -electrostatic precipitator

— fabric filter.

c. Incinerator vapor and odor control. Objectionable vapors and odors in incinerator exhaust streams sometimes necessitate specialized control systems. Odorous components present downstream of conventional cleaning systems are usually organic in gaseous or fine particulate form. Several methods available for their control are discussed below.

(1) *Afterburners.* Direct thermal incineration can be utilized to oxidize odorous fumes. A fume incineration system, or afterburner, basically consists of a gas or oil-fired burner mounted to a refractor-lined steel shell. Odorous vapors and particulate matter are exposed to a high temperature flame (1200 to 1400 degrees Fahrenheit) and are oxidized into water vapor and carbon dioxide. The principal advantages of direct thermal incineration of odorous pollutants are simplicity, consistent performance, easy modification to accommodate changes in standards, and ease of retrofit. The major disadvantage is the uncertainty and expense of fuel supply usually natural gas.

(2) *Vapor condenser.* Vapor condensers are utilized to control obnoxious odors, particularly m processes where the exhaust gases contain large quantities of moisture. Condensers can be either the direct contact type, or shell and tube surface condensers. The resulting condensate is rich in odorous material and can be sewered of treated and disposed of by other conventional methods. (See paragraph 7-4 for further information on treatment and disposal of waste materials.) Condensers are often used in conjunction with an afterburner. In such a system, exhaust gases are condensed to ambient temperature before incineration, reducing gas stream volume by as much as 95 percent and reducing moisture content. Lowering gas volume and moisture content can substantially reduce the cost and fuel requirements of the afterburner assembly.

(3) *Catalytic oxidation.* Incineration of odorous pollutants in the presence of a suitable catalyst can lower the temperature required for complete combustion and reduce the overall reaction time. Advantages of catalytic oxidation are:

— Smaller units required because lower gas temperatures reduce gas volume,
— Less oxygen required in the effluent stream since catalyst promotes efficient use of oxygen,
— Lower NO_x emissions due to lower flame temperatures and reduced oxygen loads.

(4) *The principle disadvantages are:*

— High initial capital equipment costs
— Periodic replacement of expensive catalysts

(5) *Absorbers.* Absorption systems for odor control involve the use of selected liquid absorbents to remove odorous molecules from effluent gases. The gas to be absorbed should have a high solubility in the chosen absorbent or should react with the absorbing liquid. Various methods are used to affect intimate contact of liquid absorbent and gaseous pollutant.

12-7. Technical evaluation of control equipment

a. Given the site-specific ambient air quality requirements, and the NSPS emissions limitations, and then comparing them with the uncontrolled emissions data for the combustor, it becomes possible to make a selection of various emissions controls systems to meet the emission restraints. Required is a knowledge of the various emissions control devices and their application to specific problems including their sizing and operation.

b. Other factors which must be evaluated in selecting control equipment include: site compatibility; disposition of the collected pollutant; installation and operation costs; maintainability; and the ability to provide continuous protection during operation of the combustion units. Tables 12-1 and 12-2 offer a comparison of these characteristics to serve as an aid in the final determination of the best control system for a particular application.

c. Specific operating characteristics that should be compared in evaluating suitable collection equipment are listed below. Each control device section of this manual should be consulted for specific descriptions of various control equipment.

(1) *Temperature and nature of gas and particles.* Collection equipment must be compatible with operating temperatures and chemical composition of gas and particles.

(2) *Collector pressure loss.* The power requirement for gas-moving fans can be a major cost in air pollution control.

(3) *Power requirement.* Electrostatic precipitators, scrubbers, and fabric filters have additional electrical requirements beside fan power.

(4) *Space requirement.* Some control equipment requires more space than others. This factor may, in certain cases, preclude the use of otherwise satisfactory equipment.

(5) *Refuse disposal needs.* Methods of removal and disposal of collected materials will vary with the material, plant process, quantity involved, and collector design (chap 6, 7, and 9). Collectors can be unloaded continuously, or in batches. Wet collectors can require additional water treatment equipment and if the pollutation control device uses water directly or indirectly, the supply and disposal of used water must be provided for.

12-8. Tradeoffs and special considerations

a. Design considerations. In order to design equipment to meet air pollution control requirements, the top output or maximum ratings should be used in the selection of control equipment. The additional cost for extra capacity is negligible on the first cost basis, but a later date addition could cost a substantial sum. It should also be noted whether the dust-generating process is continuous or cyclic, since an average dust concentration design may not satisfy high emissions at start-up or shut-down. Cyclic operation could also lead to problems in terms of equipment performance relative to high or low temperatures and volumes. Ductwork providing good gas distribution arrangements for a specific volume could cause significant problems if the gas volume were to increase or decrease.

b. Reliability of equipment. Since particulate control equipment is relatively expensive, and due to the fact that it is usually an integral part of the power generation process, it is of utmost importance that the equipment provide reliable service. Wrong choices of fabric for fabric filters; wrong materials of construction for wet scrubbers; the wrong choice of a multicyclone to achieve high efficiency on fine particles; can all lead to collector outages, or complete failure. Collector failures may be accompanied by a loss of production or by expensive replacement with new devices. Evaluation trade-offs should be made between costs for an auxiliary control unit and the cost of shutting down the entire process due to collector failure.

c. Space allowance. Special consideration by the design engineer must be given to provide space in the planned plant layout for adding more pollution control equipment in the future. Future plant modifications will in most cases have to meet more stringent standards than the existing NSPS.

d. Gas cooling. When high temperature (greater than 450 degrees Fahrenheit) exhaust gasses are being handled, a study should be made on the cost of installing equipment to operate at the elevated temperature versus the cost and effects of gas cooling.

e. Series operation of collectors. Dust collectors may be used in series operation for the following reasons:

(1) A primary dust collector acts as a precleaner

TABLE 12-1

RANGE OF COLLECTION EFFICIENCIES FOR COMMON TYPES OF PARTICULATE CONTROL EQUIPMENT

TYPE OF FURNACE	RANGE OF COLLECTION EFFICIENCIES - PERCENT							
	FABRIC FILTER	ELECTRO-STATIC PRECIPI-TATOR	WET SCRUBBER (VEN-TURI)	MECHANICAL COLLECTOR (MULTI-CLONE)	LARGE DIA-METER CYCLONE	SET-TLING CHAM-BER	SETTLING CHAMBER WITH WATER SPRAY	GRAVEL BED FOLLOWING A MECH. COLLECTOR
COAL								
Cyclone	95 - 99.7	65 - 99.5	65 - 99	30 - 40	20 - 30	10	NA	97-99
Pulverizers	- 99.7	80 - 99.5	80 - 99	65 - 75	40 - 60	20	NA	97-99
Spreader Stoker	- 99.7	- 99.7	- 99	80 - 85	70 - 80	20-30	NA	97-99
Other Stoker	- 99.7	- 99.5	- 99	80 - 85	75 - 85	25-50	NA	97-99
Fluidized Bed Bubbling	- 99.7	- 99.5	- 99	80 - 85	75 - 85	25-50	NA	97-99
Fluidized Bed Circulating	- 99.7	- 99.5	- 99	80 - 85	75 - 85	25-50	NA	97-99
WOOD WASTE								
Spreader Stoker		- 99.5	- 99	70 - 85	65 - 75	20-30	NA	97-99
Suspension Firing		- 99.5	- 99	60 - 80	40 - 60	20-30	NA	97-99
Municipal Incinerator	97 - 99.7	93 - 99.0	80 - 99	30 - 80	NA	30	30 - 60	97-99
Municipal Solid Waste Fired Boilers	- 99.7	- 99.5	80 - 99	30 - 80	NA	NA	NA	97-99

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TABLE 12-2
COMPARISON OF SOME DUST COLLECTOR CHARACTERISTICS

TYPE	COLLECTOR EFFICIENCY	POWER USED kW 1,000 cfm	RELATIVE COSTS	ADVANTAGES	DISADVANTAGES	RECOMMENDED APPLICATIONS	GENERAL CONDITIONS
Electrostatic Precipitator	99 + % including submicron size	2-3	2-6	High collecting efficiency for fine particles. Very versatile, collects wide variety of matter; wet or dry collection; low pressure loss and power requirement; can be used with a dry scrubber for SO_2 reduction. Can be used in high temperature (1500°F) application with favorable conditions. Medium to low operating costs.	High initial cost; sensitivity to variable dust loading and gas flow rates. Performance depends on the resensitivity of the particulate. Emission electrodes emit sparks thus precipitator not suitable for use combustible material	Coal and wood waste fired boilers; cement and lime kilns; large utility oil fired boilers; municipal solid waste fired boilers.	Low sulfur coals (including western coal) will require "hot" position precipitators or larger capacity units.
Fabric Filter	99 + %	.5-3	3-5	High collecting efficiency for fine particles. Fly-ash collection not affected by sulfur content of coal. Can be used with a dry scrubber for SO_2 reduction. Low to medium operating costs.	Fabric bags susceptible to chemical attack. Fabric materials limit the temperature and limit useful life of the fabric bags.	Coal fired boilers; municipal solid waste fired boilers; incinerators that have controlled C_rA_s temperature.	Care must be taken to protect the filter cloth from overheating, moisture, acid vapors, and mechanical stress.
Wet Scrubbers 1) Venturi 2) Dynamic	99%	4-12	1-3	Low initial cost; simultaneous gas absorption and particle removal possible; eliminates fire hazards from char and hot ash carry over.	Corrosion, erosion, scale build up problems. Disposal costs of waste water. Vapor plume. High operating costs.	Wood waste and combination wood and other fuel boilers. Coal and oil fired boilers SO_2 reductions and particulate control.	Scaling sensitive to water quality. Poor down stream separation can cause stack raining.
Mechanical Collectors							
1) Multiclone	85%	3-6	.3-.5	Low initial cost; simple operation; low to moderate pressure loses.	Low collection efficiency of fine particles; erosion problems.	Precleaner to more efficient device. Used on boiler where char reinjection is employed.	High Brinell hardness collecting tubes recommended on abrasive ash. Leave space for additional cyclones in the future
2) Cyclone	30-40	1-2	.1-.3				

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to prevent plugging, reduce abrasions, or reduce the dust loading to the secondary collector. The addition of a precleaner adds pressure drop and costs, and should only be applied where the performance of the secondary is inadequate without a primary collector of the type proposed.

(2) Mechanical collectors of the multicyclone type are usually the first choice for primary collector service. They are low cost; provide reliable collection of large diameter suspended solids in the 85 percent collection efficiency range; and can be specified in a wide variety of wear resistant metals. There are very few NSPS applications where the single or (in series) double mechanical collector can meet the particulate emission standards. Consequently, a final cleaning device of high efficiency on small size particulate should follow the mechanical collector.

(3) Utilizing a primary and secondary collector in series provides some flexibility to the system in the event there is a failure of one of the collectors.

f. Wet vs. dry collection. Factors to be taken into consideration in a comparison of wet and dry collection include:

— Solubility of aerosol
— Ultimate pH of scrubbing liquor
— Liquor corrosion and erosion potential
— Special metals or protective coatings
— Availability of make-up water
— Disposal and treatment of waste water
— Space required for liquid-handling equipment
— -Vapor plume visibility
— Operating and installed costs
— Maintenance and operation

g. Summary. A summary of the general guidelines in the selection of emission control equipment for boiler flue gases is provided in table 12-3.

TABLE 12-3

GENERAL GUIDELINES IN THE
SELECTION OF EMISSION CONTROL EQUIPMENT FOR BOILER FLUE GASES

	Boilers with less than 100 million Btu input	Boilers with 100 to 249 million Btu input	Boilers with 250 million Btu furnace input and larger
Statement on emission regulations	1. Are not regulated by the EPA's present new source performance standards. 2. Local and state air emission regulations prevail. Most states enforce laws which limit the rate of emissions based on a process weight formula designed to allow higher emission rates for the smaller boilers and decreasing the rate as the furnace input increases. 3. Controls are usually for particulate, sulfur dioxide and NO_x. Limits are usually expressed in pounds per hour or tons per year.	1. Presently the laws are the same as the smaller units. However, the EPA has proposed changes in the laws which would include boilers in this size range in their regulations. 2. Timing for the adoption or if in fact this becomes law is conjecture at this time.	1. All boilers this size must meet EPA's new source performance standards (NSPS) Coal: 0.1 lb/mm Btu of particulate; 1.2 lb/mm Btu of SO_2; 0.7 lb/mm Btu of NO_x; 20% opacity Fuel Oil: 0.1 lb/mm Btu of particulate; 0.8 lb/mm Btu of SO_2; 0.3 lb/mm Btu of NO_x; 20% opacity Nat. Gas: 0.1 lb/mm Btu of particulate; 0.2 lb/mm Btu of NO_x 2. All boilers must also meet (1) above state and local ambient air quality standards. The NSPS represent the maximum stack emissions allowed and in a great many cases will not meet the ambient air quality standards; in these cases emission rates are set by the best available control technology (BACT).
Natural gas	1. No control devices needed. 2. Laws usually cover particulate and NO_x.	1. Presently same as smaller boilers.	1. No particulate control required. 2. NO_x - requires proper burners, furnace and combustion control design.
No. 2 fuel (distillate)	1. No control devices needed. 2. Laws usually cover particulate and NO_x.	1. Presently same as smaller boilers.	1. No particulate control required. 2. No SO_2 control devices usually needed. 3. NO_x requires proper burner and furnace design and properly adjusted combustion controls.
Wood and wood wastes	1. Particulate control by multiclone mechanical collector. 2. SO_2 and NO_x are not controlled.	1. Particulate usually con- by two multiclone collectors in series. 2. SO_2 and NO_x are not usually controlled.	1. Particulate is controlled by: a. a mechanical collector followed by a wet scrubber; b. a mechanical collector followed by ESP 2. SO_2 is not controlled. 3. NO_x is controlled by properly adjusted combustion controls and special methods of distributing combustion air.
Pulverized coal (compliance) - low sulfur -	1. Particulate control by multiclone mechanical collector. 2. SO_2 controlled by use of low sulfur coal.	1. Particulate controlled by two mechanical collectors in series up to + 150 mm BTU. 2. Above the 150 mm BTU size it usually requires an electrostatic precipitator or baghouse to meet codes. 3. SO_2 controlled by low sulfur coal. 4. NO_x controlled by properly adjusted combustion controls and special methods of distributing combustion air.	1. Particulate controlled by: a. an electrostatic precipitator; b. a bag house; c. a mechanical collector followed by either a or b. 2. SO_2 controlled by low sulfur quantity in coal. 3. NO_x is controlled by properly adjusted combustion controls and special methods of distributing combustion air.
Pulverized coal (high sulfur)	1. Particulate and NO_x are same as compliance coal. 2. Where state limits will be exceeded by SO_2, the hours of operation will have to be limited or an SO_2 scrubber will be required.	1. Particulate and NO_x are controlled the same as on low sulfur coal. 2. SO_2 emissions are usually controlled by a wet scrubber in series with an electrostatic precipitator and located down stream of the I.D. fan. Dry scrubbers are employed in series with either a baghouse or electrostatic precipitator. The dry scrubber is located directly up stream of the particulate collector.	1. Particulate and NO_x are controlled the same as shown for low sulfur coal. 2. SO_2 is controlled by either a wet or a dry scrubber. - Wet scrubbers are usually located just up stream of the stack. - Dry scrubbers are located directly upstream of either the baghouse or the electrostatic precipitator.

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